Determinants of agriculture biodiversity in Western Terai landscape complex of Nepal

Paudel, Bikash and Rana, Ram B and Sthapit, Bhuwon R and Maharjan, Shree Kumar and Shrestha, Anuja and Shrestha, Pitambar and Gurung, Asha Ram and Regmi, Bimal Raj and Basnet, Arjun and Adhikari, Anu

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B Paudel[1], R.B. Rana[1], B. Sthapit[2], S.K. Maharjan[1], Pitambar Shrestha[1], A Shrestha[1], A. Gurung[1], B. Regmi[1]; A. Basnet[1] and A. Adhikari

[1]Local Initiatives for Biodiversity Research and Development (LI-BIRD), Pokhara – 4, Gairapatan, Kaski, Nepal; P.O. Box 634, [2] Bioversity International, New Delhi 110 012, India

1. INTRODUCTION

1.1. Agriculture biodiversity

Agricultural biological diversity (CBD 2000), agricultural biodiversity (Thrupp 2000; Reidsma, Tekelenburg et al. 2006), diversity in agriculture landscapes (Duelli 1997), farmland biodiversity (Van Buskirk and Willi 2004) (Dennis and Fry 1992; Firbank and Forcella 2000; Benton, Vickery et al. 2003; Butler, Vickery et al. 2007) and agrobiodiversity (Wood and Lenné 1999; Bardsley 2001; Bardsley and Thomas 2006; Birol, Smale et al. 2006) are different terms used for defining sub-sets of biological diversity of relevance to food and agriculture that constitute the agro-ecosystem. The Convention on Biological Diversity, in its 5th Conference of Parties (COP) defined agriculture biodiversity as all the varieties and variability of animals, plants and micro-organisms, at the genetic, species and ecosystem levels, which are necessary to sustain key functions of the agro-ecosystem, its structure and processes (CBD 2000). While biodiversity generally refers to species variation, we will also consider genetic diversity that represents the heritable variation within agriculture ecosystem (Ramanatha Rao and Hodgkin 2002). The term crop genetic diversity is used (Di Falco and Perrings 2003; Smale, Bellon et al. 2004; Esquinas-Alcazar 2005), to indicate intra-specifies genetic diversity of crops, which can be easily understood by diversities of verities and landraces of a crop.

Maintenance of agriculture biodiversity is essential for feeding humanity, maintaining environmental health and sustainable development (CBD 2000; Esquinas-Alcazar 2005). Diversification of agriculture is one of the key options to food security of local people (UNEP 2008). Agriculture biodiversity and crop genetic diversity is considered to be an asset for adaptation to current environmental changes (FAO 2008; Sthapit, Rana et al. 2008; Vigouroux, Barnaud et al. 2011); reduce risk exposure (e.g. crop failure) (Di Falco and Chavas 2006). Intra-specific crop diversifications have been also found to an effective ecological approach to disease and pest control (Baliddawa 1985; Zhu, Chen et al. 2000; Cutforth, Francis et al. 2001), which ultimately contributes to reduce the negative environmental footprints of agriculture. Moreover, many local varieties – which are important component of crop genetic diversity, have qualitative traits such as preferred food, better nutrition, adaptive to low input conditions, co-adaptive complexes, yield stability, specific niche suitability, and socio-cultural significance (Sthapit, Rana et al. 2008; Burlingame, Charrondiere et al. 2009). Many have already acknowledged alarming rate of erosion of agriculture biodiversity (Shand 2000; Esquinas-Alcazar 2005; FAO 2009), and realized the need of conservation (FAO 2009). Given the enormous interdependence of indigenous people and rural poor on genetic diversity, this loss raises critical socio-economic, ethical and political questions (Esquinas-Alcazar 2005). It shows inevitability of the directing our efforts to conservation and sustainable use of agriculture biodiversity.

Nepal is a small country with very rich in biodiversity (MoFSC 2002; Gautam 2008). Particularly to agriculture biodiversity, only the accessions collected and stored in gene bank of Nepal include 4715 of 11 cereal species, 977 millets, 383 pseudo cereals, 3357 pulses, 640 oilseeds, 603 vegetables, 75 spices, 11 fiber crops and 20 other accessions (Gautam 2008). But this richness is in verge of extinction threats (Maikhuri 1996; Gautam 2008).

The Western Terai Landscape Complex (WTLC) is globally significant with regard to both its faunal and floral diversity. Although there is no complete information on the flora of this entire landscape, it is estimated that the Western Terai Landscape Complex has about 900 species of vascular plants, out of which 455 species have been recorded (WTLCP 2012). More than 80 per cent of the people do agriculture in WTLC. The region is rich in agriculture biodiversity reflected by high diversity of paddy, barley and millets (WTLCP 2006; Maharjan, Gurung et al. 2011). The region is hotspot of in-situ conservation. Inside Nepal, WTLCP has Bardia National Park (BNP) with area of about 968

Square Kilometer (sq. km.) and about 327 sq. km buffer zone; Shuklaphanta Wildlife Reserve (SWR) with an area of 305 sq. km. and buffer zone of 153 sq.km. Dudhawa National Park (DNP) and Katarniaghat Wildlife Sanctuary (KWS) are also in very near bordering areas of India. Western Terai Landscape Complex Project (WTLCP), a joint initiative of Government of Nepal with many other stakeholders, has been using landscape management approach for the establishment and conservation of the three biological corridors—named Laljhadhi, Basanta and Khata to inter-connect BNP, SWR and *Chure* forests of Nepal with DNP and KWS of India.

1.2. Factors affecting agriculture biodiversity

Agriculture biodiversity depends on ecological factors as well as factors which affect decision making of the farmers such as economic and social status of households and access to information and technology (Giampietro 1997; Heal, Walker et al. 2004; Rana, Garforth et al. 2007; Bajracharya, Rana et al. 2010). Rana, Garforth et al. (2007) reported number of parcels of land, access to irrigation, membership in farmers' groups and use of insecticide were have significant positive influence on varietal diversity of rice in Nepal. Similarly, they also suggested that number of parcels of land, livestock number, agro-ecology (altitude), and use of chemical fertilizer have a significant positive influence on landrace diversity, while membership in farmers' groups linked to extension services negative influence on diversity of local varieties. Similarly, (Joshi, Subedi et al. 1998) stated no single socio-economic cause appears to be responsible for genetic erosion of finger millet (*Eleusine coracana*), but mentioned introduction of high yielding varieties was a major factor.

FAO (2009) recognizes the prospects offered by sustainable agriculture for reducing the negative impacts on biological diversity, enhancing the value of biological diversity and linking conservation efforts with social and economic benefits. García-Frapolli, Ayala-Orozco et al. (2007) suggested that biodiversity conservation is compatible with traditional agriculture and Bardsley and Thomas (2006) suggested the potential of agrobiodiversity based development model for Nepal. Since, the mission of protected areas has been broadened from conservation to improving human livelihood (Naughton-Treves, Holland et al. 2005), mainstreaming agriculture biodiversity conservation in landscape management is gaining momentum. Although, agriculture biodiversity conservation efforts in past had focused on ex-situ, the need of in-situ conservation for continuation of biological and social processes of crop evolution has also been realized (Brush 1994). This can be done cost-effectively through adopting landscape approach and inclusion of agriculture biodiversity in larger framework of in-situ conservation. Brandon, Gorenflo et al. (2005) indicated that the conservation efforts in form of protected areas have positive effects on agriculture biodiversity. WTLCP also tries to enhance biodiversity conservation and sustainable livelihoods to ensure an enabling environment for biodiversity management across both productive and protected sectors (WTLCP 2010). But, the effects of these large scale conservation efforts in Western Terai region of Nepal to agriculture landscape is not completely known and worth evaluating.

In that context, the overall purpose of the study was to analyze whether the in-situ conservation efforts in WTLC in the form of protected areas, have any effects on agriculture biodiversity of the region. Specifically, we analyzed the difference in agriculture biodiversity across a spectrum of different land-uses around protected areas in WTLC and identified the factors determining richness of agriculture biodiversity in farming households.

2. METHODOLOGY

2.1. Data Sources

The data for the study was collected through personal interviews with 907 household heads in six village development committees (VDCs) of Western Terai Landscape Complex. I applied stratified random sampling method taking VDC as strata, to select about 9 percent of the total households in village. Social, economical, technological characteristics of the households, as well as richness and evenness attributes of household agriculture biodiversity in species and variety level; were collected through structured survey questionnaire.

2.2. Analysis methods

Diversity was analyzed in intra-species and inter-species level. Intra-species diversity was analyzed for rice, wheat, maize, potato and mango, where species diversity was analyzed for vegetables, fruits, fodder and forage. Intra-species diversity of local varieties of rice, wheat, maize, potato and mango was also separately analyzed.

The richness of intra-species diversity of rice, wheat, maize, potato and mango were estimated as the total numbers of varieties. The richness in inter-species diversity of vegetables, fruits, fodder and forage were estimated by counting the total numbers of species. We calculated Shannon- Weaver Index (SW Index – H') and Evenness Index (E) for these intra and inter-species levels. SW index was chosen because it combines richness and evenness to produce a single index (Wimp, Young et al. 2004). We estimated evenness index based on SW index and total richness as done by (Metzger 1997).

Table 1: List of explanatory variables used for model fitting and their specifications

Variables	Specification of the variable
Age of HH head (Years)	Age of household heads (years)
Duration of stay	Duration of stay of family in village (years)
HH labor	Member of households who work as agriculture labor
Food security	Total months for which the household production can feed the household member.
Animal holding	Animal holding was transferred to cattle equivalent unit. The conversion factors were 1.25 for buffalo, bull and horses, 1.00 for cattle, 1.19 for improved cattle, 0.25 for pigs, 0.13 for small ruminants like goat and sheep, 25 per 1,000 rabbits, and 12.50 per 1,000 head of poultry.
Land holding	Total land owned by households in hectare
Total family Income	Total family income from both farm and non-farm sources in USD
Technology Index	Discrete continuous variable: We took five indicative practices of modern technologies i.e. use of improved varieties, chemical fertilizer, pesticides, hybrid varieties and commercial farming. We counted how many of these have been practiced by each household to estimate index ranging from 0 to 5.
Information Index	Discrete continuous variable: We took five household characteristics indicative of access to information i.e. being member of farmers' group, if some-one in household received agriculture training, participated in exposure visits, got orientation on conservation, and used government extension services. We counted how many of these have been practiced by each household to estimate index ranging from 0 to 5.
Settlement	Binomial variable i.e. cluster settlement of households and scattered settlement of households
Seasonal labour	Binomial variable i.e. go to seasonal labor work, do not go to seasonal labor work
Family type	Binomial variable i.e. nucleus and joint family
Shared/rented land	Binomial variable i.e. with and without shared/rented in land
Irrigation facility	Binomial variable i.e. with and without irrigation
Ethnicity	Categorical variable, indicate the cast of household. It had 6 category i.e. Brahmin/Chettri, Dalit, Rana Tharu, Chaudhary Tharu, Muslim and others
Education of HH head	Categorical variable indicating education of household head. It had five categories i.e. Primary, Secondary, >Secondary, Illiterate, literate but informal
Land use type	Categorical variable, which indicated the land use type i.e. Buffer zone, Corridor, Intensive Agriculture

To identify the factors affecting richness of household agriculture biodiversity, we used multivariate Poisson regression models estimated through generalized linear regression process. The number of varieties of rice, wheat, maize, potato and mango and number of species of vegetable, fruit, fodder and forage was taken as response variables. Being the count of the varieties or species, response variables were expected to have Poisson distribution, and histograms of the variables supported the assumption (look supplementary material figures, SM 1). Those response variables were fitted against 17 possible explanatory variables including status of social (5 variables), economical (3 variables), resource condition (3 variables) of households, factors for access to technology and information (3 variables), factors about characteristics of decision makers (2 variables) and one factor of land-use. The complete list of explanatory variables with their specification is presented in Table 1. The correlation matrix of all

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3. RESULTS AND DISCUSSION

3.1. Socio-economic characteristics of the regions

About 66 percent households in the regions were in clustered settlements, whereas about 62 percent of them were joint families. The average family size was 8.04 person per family, which was significantly higher (p value = 0.01) than the national average of 5.8 in Nepal.

Table 2 shows that the average land holding was about 0.92 hectare, which was comparable to national average of 0.96 hectare. Animal holding converted to Cattle Equivalent (CE) using Hayami and Ruttan (1985) conversion factors showed it was 3.97 CE per households and about 57% of the household graze their animals in some common place. The food self-sufficiency of the region is about 9.8 months, which is lower than the total Terai region. The average cash income of the family was about $ 605.8. About 26 percent of total farmers cultivate others land, either in crop sharing mode or by taking land in rent. The ethnic composition, education status, household structure, seasonal migration and availability of irrigation facility among the respondents have been provided in SM 2. The region is dominated by two indigenous Tharu communities, who constituted about 47 percent of total households together (SM2). About 68 percent of household heads were illiterate and about 64 percent households were joint households. Seasonal migration for work is very common pattern in the region, which is reflected by about 33 percent of households had some members gone for seasonal works. About 65 percent of households have land with irrigation facility, but most of land lack year round irrigation.

Table 2: Socio-economic conditions of households by land-use type

Variables	Land-use types			Overall
	Buffer Zones	Corridors	Intensive Agriculture	
Age of HH head	48.4±0.7[€]	47.6±0.8	46.3±0.8	47.4±0.4
Years of stay in village	34.0±1.2	34.6 ±1.4	38.3±1.1	35.6±0.7
Technology Index	2.3±0.0	2.9±0.0	2.7±0.0	2.6±0.0
Information index	0.8±0.0	0.7±0.0	0.9±0.0	0.8±0.0
Farm labor	3.8±0.1	4.9±0.2	4.6±0.1	4.4±0.1
Food sufficiency	9.3±0.2	10.6±0.2	9.8±0.2	9.8±0.1
Cattle equivalent	2.9±0.1	3.5±0.1	2.9±0.1	3.1±0.0
Total Land (Ha)	0.8±0.0	1.0±0.1	0.9±0.0	0.9±0.0
Total family income (USD)	3.4±0.1	3.4±0.1	3.6±0.1	3.5±0.0

[€] indicate mean ± SE of mean

3.2. Factors affecting Intra-species diversity of major crops

The richness, SW index and evenness index of intra-species diversity of major crops in WTLC are presented in Table 3. Results indicated that the region was very rich in intra-species agriculture biodiversity. We found about total of 52 including 13 local varieties of rice (*Oryza sativa*), 9 including 4 local varieties of maize (*Zea mays*), 22 including 4 local varieties of wheat (*Triticum aestivum*), 11 including 4 local varieties of potato *(Solanum tuberosum*) and 11 including 4 local varieties of mango *(Mangifera indica*) maintained by farmers.

The coefficients of five multivariate Poisson regression models for overall intra-species diversity and five separate models for local varietal diversity were estimated to identify the factors affecting the diversity in households. The level of significance of variables and

Table 3 Intra-species diversity of major crops by land use type in WTLC

Land use	Parameter	Rice		Wheat		Maize		Potato		Mango	
		All	Local	All	Local	All	Local	All	Local	All	Local
Buffer zone	Richness	43[ς]	10	12	4	8	3	10	4	10	4
	SW Index	2.79[€]	1.86	1.58	1.11	1.13	0.60	1.89	1.01	1.65	0.89
	Evenness	0.74[£]	0.8	0.51	0.8	0.54	0.55	0.82	0.73	0.72	0.58
Corridor	Richness	27	7	17	3	8	2	9	3	7	4
	SW Index	2.03	1.17	1.59	0.93	1.14	0.59	1.45	0.75	1.51	0.98
	Evenness	0.61	0.6	0.56	0.85	0.54	0.85	0.66	0.68	0.77	0.71
Intensive Agriculture	Richness	31	6	15	2	6	2	8	3	10	4
	SW Index	2.46	0.78	1.08	0.59	0.98	0.15	1.47	0.77	1.37	0.85
	Evenness	0.71	0.4	0.49	0.84	0.55	0.21	0.71	0.7	0.6	0.61
Total	Richness	52	13	22	4	9	4	11	4	11	4

[ς] indicate the total numbers of varieties grown by different farmers in the respective land-use hence can be understood as the richness parameter
[€] indicate the Shannon-weaver index estimated for the respective land-use
[£] indicate the Evenness Index estimated for respective land-use

Table 4 Factors affecting intra-species diversity of major crops

Variables	Rice		Wheat		Maize		Potato		Mango	
	All	Local	All	Local	All	Local	All	Local	All	Local
Intercept	-26.92***	-4.48***	-1.06***	-2.760***	-1.27***	-3.33***	-0.33**	-0.768***	-28.91***	-28.77***
Quantitative variables										
Technology Index	0.09*		0.12***		0.11***		0.10***		0.26***	0.24***
Information Index									0.16***	0.18***
Farm Labor (HH members)	0.02**	0.03	0.02**			0.08*			0.04*	
Food sufficiency (months)	0.02**		0.02**		0.02**		0.01**			0.03*
Animal holding (CE)	0.04**	0.09*	0.05*		0.04*				0.07**	
Total land (Ha)	-0.03**				-0.03					
Total Family Income (USD)						-0.07*				0.07**
Age of HH head (Years)			-0.01***							
Stay in village (years)	0.01***	0.009***								
Type of settlement										
Categorical variables										
Ethnicity		***			**	**			***	
Education of HH head		*								
HH type	*	***								
Seasonal work outside village									***	***
Cultivate others land	***								***	**
Irrigation facility	***	***		***				**	**	
Land use type	**	***	***	***		*	**	***	***	***

Note: ***, **, * indicates the coefficient was significant at 99, 95 and 90 per cent confident level, respectively**.** The values of the co-efficients for quantitative variables and levels of significance for categorical variables are presented in the table. The detail of nature of relationship of the categorical variables is presented in Appendix B.

direction of relationship of continuous variable is presented in Table 4. The details of the coefficients for each category of significant categorical variables are provided in Appendix B.

Technology index was found to positively and significantly associate with total varietal diversity of all crops, but it was not significantly associated with diversity of local varieties. The result indicated that as farmers have higher access to agriculture technologies, they start to grow new varieties, but still continue to grow the older ones. The finding was in contradiction with some of the previous reports. Upreti and Ghale (2002) which mentioned adoption of modern technology would reduce the local biodiversity, and decrease the total diversity; but similar to the conclusion of Burel, Baudry et al. (1998) who indicated intensification in agriculture do not always decrease the richness. The adoption of modern technology like irrigation, fertilization, use of insecticide, improved and hybrid varieties put pressure on local varieties. If the local varieties have some preferred character in term of social, economical or cultural significance, farmers also keep local varieties, which reduce evenness but do not reduce richness. Moreover, the introduced varieties increase total richness.

Information index (indicating access to trainings, visits, orientation, extension, farmers' group) was found to have significant positive association with varietal diversity of mango, but not related to varietal diversity of other crops. The result is logical because access to information not only imparts knowledge about importance of fruits and increases the consumption of fruits (Jaime and Monteiro 2005) but also improve access to planting materials. Most of the times, information regarding fruits is soughed by the farmers, and planting material of fruits makes their primary interest.

Farm labor was identified as significant factor affecting varietal diversity of total rice, wheat and mango; and local maize and local mango. The findings were similar as reported by Benin, Smale et al. (2004). Households with more labor would afford to grow more varieties, if they wish to grow, because to grow more varieties, it will require more labor. Similarly, most of the local varieties are also labor intensive in nature.

Food security was positively and significantly associated with total varietal diversity of all crops, except in mango it was significantly associated with local varietal diversity. It is expected because farmers having better food security would try for quality produces, which definitely drive them to increase the diversity in food. Animal holding was also identified as major variable to significantly and positively affect total varietal diversity of rice, wheat, maize and mango; and diversity of local rice. Similar findings were also reported by previous studies (Cutforth, Francis et al. 2001; Rana, Garforth et al. 2007). Straw of these cereals is major source of feed for animals during scarce period of year in the region (Sharma 1990); people with higher number of animals need diverse type of straw to feed animals. Among these, rice straw is the most common feed and local rice varieties produce more straw than improved. Hence, it was logical that higher the animal holding, farmers opted to keep higher local rice diversity.

Total land holding was found significant but with negative association with total rice varietal diversity. The findings did not matched with the findings of Bajracharya, Rana et al. (2010) who suggested resource-rich farmers were the main custodians, but similar to the result of Cutforth, Francis et al. (2001) and Jarvis, Brown et al. (2008). Rana, Garforth et al. (2007) had reported number of parcels of land was significant variable to affect rice varietal diversity rather than land holding. So, inclusion of number of parcels would have given better picture of relationship.

Total family cash income was negatively associated with varietal diversity of local maize, and positively associated with that of local mango, which was similar to the result of Cutforth, Francis et al. (2001). Maize in the region is not the main staple food, hence farmer sell most of the maize. Hence, local maize produces less, farmers who try to get higher cash income grow improved or hybrid variety. Age of household age was found to be negatively associated with varietal diversity of wheat, indicating resistance of old farmers to adopt new varieties. Length of permanent stay in same village was found positively associated with varietal diversity of rice, indicating the significance of strong traditional seed exchange and storage practice in the region.

Ethnicity was found to be significant factor for diversity of local rice similar to the report of Sthapit, Rana et al. (2008), which signified rich diversity kept by Tharu communities. Tharu communities keep some of the local varieties of rice for their ritual needs and celebrations. Interestingly, higher education of household head was associated with lower diversity of rice, which indicated educated farmers wanted specialized farming. Similarly, results suggested higher rice varietal diversity of joint families. Households with members gone for seasonal migration tended to have higher mango diversity; which would be explained by the higher access to diverse planting materials outside village.

Availability of irrigation facility was found as important factor. The households with irrigation facility had higher diversity of total rice, local rice, and local maize and local potato. This result supports the findings of Rana, Garforth et al. (2007) and (Bajracharya, Rana et al. 2010) but reject the suggestion of (Brush 1994) who suggested higher adversity in farming system, in this case, might be without irrigation facility, should have more diversity.

Land-use type was significant for diversity of rice, wheat, and mango, local maize, total potato. Overall varietal diversity and local varietal diversity of rice and mango, local varietal diversity of wheat was highest in buffer zone. Thus it indicated that buffer zone has highest diversity of majority of the crops, and that is very true in case of local varietal diversity. For non-indigenous crops like wheat, it was highest in corridor and for potato the diversity was highest in intensive agriculture land-use. This is logical because wheat and potato are the crops taken from outside not very ago in history. Thus, overall the results indicated strong positive effect of landscape conservation on the varietal diversity of local crops, but it was not as strong and not similar for imported species.

3.3. Factor affecting inter-species diversity of agriculture

Inter-species richness of agriculture biodiversity categorized according to their use type, i.e., vegetables, fruits, forage and fodder by land-use types is presented in Table 5. Results showed that farmers in intensive agriculture land-uses kept highest richness of vegetables; whereas farmers in buffer zones kept highest diversity of fruits; and farmers in buffer zones keep highest number of forages and fodders species.

Table 5 Inter-species diversity of agriculture biodiversity in WTLC

Land-use types	Diversity parameters	Vegetables	Fruits	Forages	Fodders
Buffer zone	Richness	39 [ς]	33	29	20
	SW Index	3.24 [€]	2.57	2.29	2.58
	Evenness	0.88 [£]	0.74	0.74	0.69
Corridor	Richness	39	35	25	14
	SW Index	3.21	2.73	1.99	2.55
	Evenness	0.88	0.77	0.74	0.69
Intensive Agriculture	Richness	40	33	24	17
	SW Index	3.18	2.77	2.21	2.5
	Evenness	0.86	0.79	0.72	0.73
Total	Richness	43	36	42	35

[ς] indicate the total numbers of species maintained by different farmers in the respective land-use hence can be understood as the richness
[€] indicate the Shannon-weaver index estimated for the respective land-use
[£] indicate the Evenness Index estimated for respective land-use

Results indicated that the effects of land-use were visible in inter-species agriculture diversity. For most of the intra-species, and inter-species richness, buffer zone was highest. That was even strongly true in case of local varieties of crops. But, the evenness of the distribution was not as high as richness in buffer zone, which indicates the varieties, might be in danger of extinction or in pressure of marginalization. Overall, result suggested that the agriculture biodiversity was positively affected by landscape conservation efforts but introduction of new varieties and species has also increased the total genetic pools.

Multivariate Poisson regression model was fitted for four response variables, i.e. number of species in vegetables, fruits, forages and fodder. Table 6 shows contin-

Table 6 Factors affecting inter-species diversity of agriculture biodiversity

Variables	Vegetable	Fruits	Forage	Fodder
Intercept	0.583	1.063***	-0.839***	-0.537
Technology Index	0.05***	0.10***	0.11***	0.11***
Information Index	0.05***	0.04**	0.08**	0.16***
Farm Labor (HH members)		0.01*	0.03**	-0.02*
Food sufficiency (months)	0.01	0.01**	0.02***	
Animal holding (CE)		0.03***	0.04***	0.08***
Total land (Ha)	-0.02***	-0.02*		
Total Family Income (USD)	0.01*			
Age of HH head (Years)		0.002*		0.006
Stay in village (years)	0.002***		0.003	
Type of settlement				***
Ethnicity	***	***	*	***
Education of HH head	***			
HH type	**			
Seasonal work outside village	***			
Cultivate others land	*			
Irrigation facility				***
Land use type	***	***	***	

Note: ***, **, * indicates the coefficients were significant at 99, 95 and 90 per cent confident level, respectively. The values of the co-efficients for quantitative variables and levels of significance for categorical variables are presented in the table. The detail of nature of relationship of the categorical variables is presented in Appendix C.

uous variables given with respective coefficients in the model with level of significance, and categorical varia

bles given with level of significance. The coefficients of the each level of significant categorical variables are presented in Appendix C.

Technology index and information index were significantly and positively associated with all the diversity values. While improved technology also include new crops and new varieties, and increased access to information not only provide knowledge about new diversity to the farmers, but improve access to seed and planting materials, increased technology index and increased information index had positive relationship with the diversity. In most of the cases, increased technology has been blamed to have negative impacts on diversity, but if local diversity is protected in the process, it increases the overall diversity.

Farm labor was positively associated with forage diversity, and negatively associated with fodder diversity; which signified that with higher availability of labor, farmers grow more forage, and less fodders. With limited land holdings, forage is the choice of the farmers if they can afford the time need of household labor. With less family labor, farmers can grow lower area, and allocate higher area to grow fodder.

Food self-sufficiency was also positively associated with diversity of vegetables, fruits and forage. Higher animal holding was positively associated with higher diversity of forage, fodder and fruits. The relationship of animal holding with forage and fodder diversity was easy to understand because with higher animals, farmers needs higher amount of fodder and forage, which corresponds with higher diversity. Many times, fruits are also treated as fodder, which ultimately led to positive relationship of fruit diversity with livestock holding. Total land holding was negatively associated with vegetables and fruits diversity, which was very unconventional and worth further investigation.

Total family income was positively associated with vegetable diversity, which signified the higher number of vegetables grown and eaten by richer families. When people get richer, they want more nutritive and diverse diets, which is reflected by the higher number of diversity.

Ethnicity was significant for most of this diversity, indicating the importance of *Tharu* community in biodiversity conservation. *Tharu* community is a native ethnic community of the region who has very strong customary, traditional and religious bond with the local biodiversity hence they protect rich biodiversity as the way of their life.

Education of household head was significant for vegetable diversity, which indicated that with more education, farmers grow and eat more vegetables. Similarly, joint family was found to have higher vegetable diversity. The households with a member gone for seasonal work had higher vegetable diversity, which must be because of knowledge about new vegetables and improved access to seed outside the villages. The relationship of land tenure was on vegetable diversity, where farmers without rented-in/shared-in land had higher diversity. Irrigation facility was negatively associated with fodder diversity, which was because, irrigated lands are generally cultivated for field crops, and fodders are not maintained.

Land-use type was significant in case of vegetable, fruit and forage diversity. For vegetables and fruits, productive agriculture land-use was richest, because that land-use had combination of the native and introduced fruits and vegetables, whereas buffer zone has more of native diversity. But for forage, corridors were richest. These results indicated species diversity could be increased with introduction of non-native fruits, vegetables, forage and fodders in agriculture lands if the local diversity is maintained and conserved.

4. CONCLUSION

The analysis of the intra-species richness indicated intra-species diversity of major crop i.e. rice, maize, potato and mango was higher in buffer zone and it was particularly always true for local varieties. Thus, result suggested significant contribution of landscape level in-situ conservation efforts in form of national parks and wildlife reserves, and their buffer zones, in conservation of local varieties. However, evenness indices of buffer zone were not always highest, which indicated the gradual marginalization of local varieties suggesting possible threats for conservation of the rich agriculture biodiversity in buffer zones. Thus it is concluded that on-farm conservation of agriculture biodiversity is feasible in buffer zones of in-situ conservation hotspots and coordinated efforts and strong internalization of agriculture biodiversity conservation agenda in buffer zone management efforts in landscape conservation efforts are needed.

The analysis of factors affecting richness of intra-specifies and inter-species agriculture biodiversity identified complexity of the nature of the relationship determining the biodiversity richness in households. Despite common belief, access to information, modern technology, and modern agriculture practices did not have negative effects on the diversity in WTLC, which indicate if introduction of modern technology is coupled with efforts of conservation of local varieties or species, which ultimately increase the total diversity in the pool. Economic variables like food security, household resource variables like animal holding and land holding were important variables for maintenance of agriculture biodiversity, which suggested the need of coordinated efforts for livelihood improvement and biodiversity conservation in the region. Social factors such as ethnicity, seasonal migration, land tenure and education were also important determinants of diversity, indicating strong need of proper consultation and collaboration of the communities, especially the Tharu ethnic communities, while designing and implementing any conservation efforts on landscape level.

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